Tests of Potassium Superoxide Canisters in a Small Fallout Shelter

VERNE L. BRECHNER, M.D., ROBERT O. BAUER, M.D., ROBERT F. WOLFF, M.D., ROBERT W. M. BETHUNE, M.D., and JOHN B. DILLON, M.D.

THE REQUISITES of oxygen supply and carbon dioxide removal for a closed environment suitable for human inhabitants are most easily fulfilled by mechanically circulating filtered air from the outside atmosphere into the closed environment and then exhausting it to the outside again. Such a system, with a manually driven blower serving as the mechanical force for circulating the air, is used in most family fallout shelters.

Under some circumstances a fallout shelter would have to be sealed from atmospheric air, for example, during chemical or biological contamination of the atmosphere or a fire storm at ground level. Although occupants could use air contained in the shelter for several hours, an auxiliary method of supplying oxygen and removing carbon dioxide would lengthen the period of shelter survival.

Three oxygen sources may be considered practical for auxiliary use during sealed-shelter occupancy—tanked compressed oxygen, chlorate candles, and KO_2, potassium superoxide (*1*). Although compressed oxygen and chlorate candles provide a large volume of oxygen, they offer no means of extracting carbon dioxide from a contained atmosphere. In the potassium superoxide method, however, water vapor and carbon dioxide are used to produce oxygen by the following formula:

$$4KO_2 + CO_2 + H_2O \rightarrow 2KOH + K_2CO_3 + 3O_2$$

A large-volume KO_2 canister presently available for atmospheric control of fallout shelters is purportedly capable of supplying 72 man-hours of oxygen in combination with carbon dioxide absorption (*A*). (Its functional characteristics will be the subject of a future investigation.) Potassium superoxide is also used in self-contained rebreathing rescue apparatuses (*B*). For such purposes it is packaged in copper canisters containing 500 grams of chemical (*2*).

For economy in the small family shelter and to supply atmospheric control during shorter periods than 72 man-hours, we have investigated the feasibility of using smaller canisters.

Methods

Site of observations. All observations were made in a fallout shelter under simulated conditions of prolonged occupancy. This shelter consisted of a steel tank 10 feet in diameter and 7 feet in height, buried under 3 feet of earth and covered at ground level by a 6-inch-thick slab of cement. Entrance to the shelter chamber was gained through a vertical shaft of galvanized iron, 8 feet long and 3 feet in diameter, extending from the ground level to the floor level of the shelter. The vertical shaft was covered with a steel hatch.

The shelter was connected with the outside atmosphere by an entrance shaft; an air intake duct (3-inch diameter), connected to the hand-driven blower (*C*) by a flexible conduit; an exhaust duct (3-inch diameter); and an aerial

The authors are on the faculty of the University of California, Los Angeles, School of Medicine, department of surgery/anesthesiology. *The work described was supported in part by a grant from the Public Health Service, NB 04138–01.*

shaft (1-inch diameter). To observe alterations of the gaseous content of the shelter, we sealed the exhaust and aerial ducts with a threaded steel cap, detached the flexible conduit of the air intake duct from the blower and immersed it in water, and covered the hatch over the entrance shaft with a plastic sheet.

Instrumentation. Oxygen concentrations were measured by means of a Beckman D3 paramagnetic analyzer with a full-scale range of 0–25 percent (fig. 1). Oxygen concentration of more than 25 percent was determined by a similar instrument with a range of 0–100 percent. Carbon dioxide concentrations were determined with a Liston Becker LB–16 infrared analyzer. Three-point calibration was used in a range of from 0 to 5 percent, and zero adjustment was made with carbon dioxide-free compressed air. The flow rate of gases circulated through various canisters, as described in the next paragraph, was measured with a Meriam B–627 differential manometer flow meter, calibrated against a 600-liter spirometer. The temperature and relative humidity of the shelter were recorded with a Serdex hydrothermograph 310.

Protocol. The investigation was conducted in three phases, to determine: (*a*) the rate at which oxygen was extracted and carbon dioxide accumulated in a sealed shelter inhabited by two adults; (*b*) the functional characteristics of a commercially available 500-gram KO_2 canister in oxygen generation and carbon dioxide absorption under conditions of shelter use; and (*c*) the efficiency of a larger 1,250-gram KO_2 canister under similar circumstances.

Experiments and Results

Phase 1

To fulfill the first phase of the study protocol, rates of oxygen consumption and carbon dioxide accumulation were observed in the shelter when it was occupied by two adults and sealed as already described. The contained atmosphere

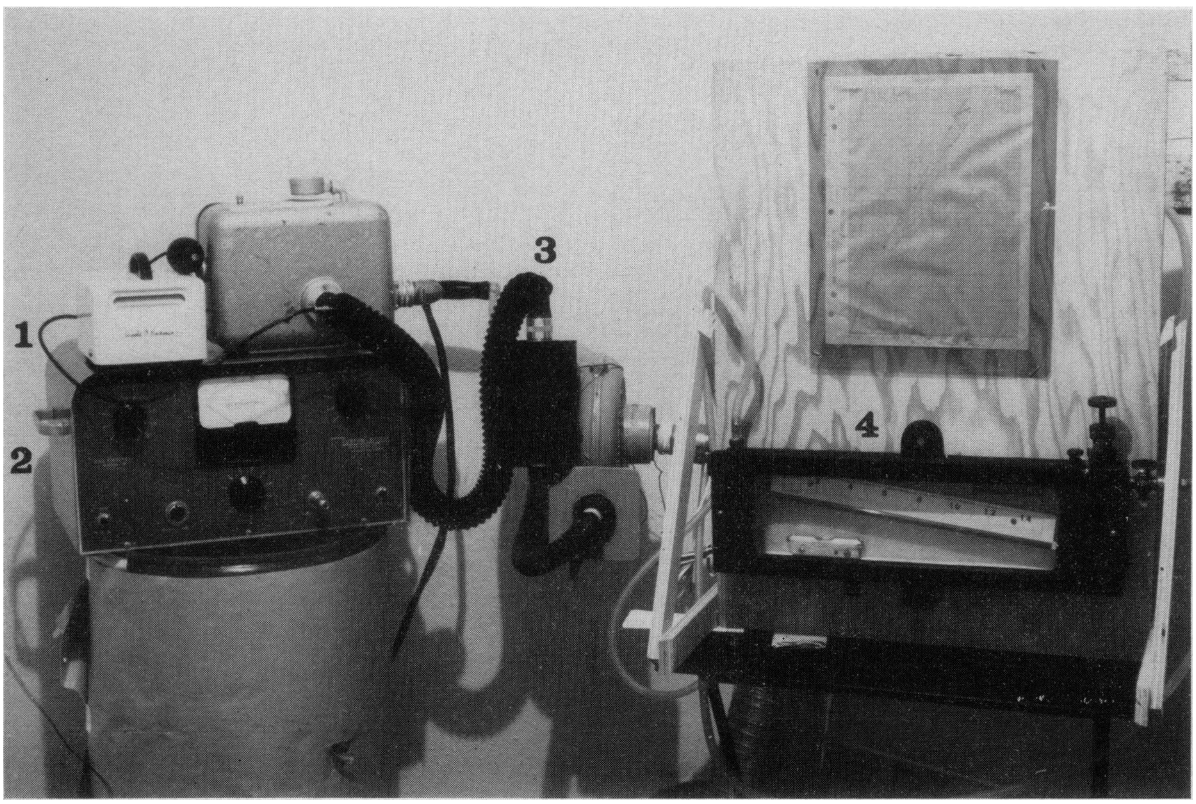
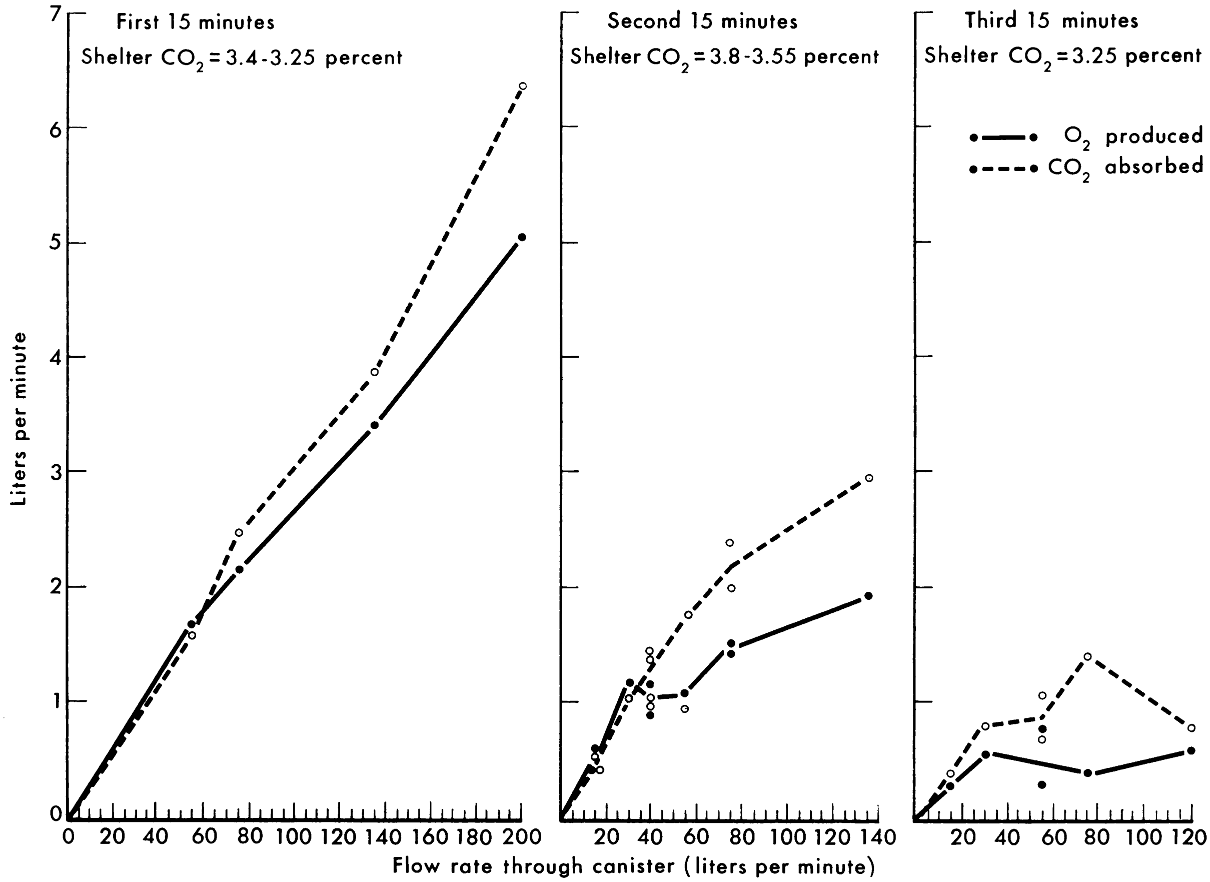


Figure 1. Instrumentation used in shelter observations: 1. Beckman D3 paramagnetic analyzer, 2. Liston Becker LB16 infrared analyzer, 3. Chemox 500-gram potassium superoxide canister and manually operated blower, 4. Meriam B–627 differential monometer flowmeter

Figure 2. Phase 2: Effect on oxygen production and carbon dioxide absorption of varying the flow rates of atmosphere circulated through a 500-gram canister



was circulated continuously within the shelter at a rate of 75 liters per minute by means of a manual blower, each occupant alternating a 15-minute period of labor at the blower with 15 minutes of rest. Oxygen and carbon dioxide concentrations were measured at 5-minute intervals. The observation extended over a 4-hour period.

As expected, the volume of air contained in the shelter before it was sealed provided a reservoir of oxygen; the oxygen concentration remained at 20 percent for the first hour of occupancy. During the second and third hours, it remained at 19 percent or more; during the fourth hour, it was 18.5 percent. Carbon dioxide concentration increased steadily during the 4 hours. It was 0.5 percent at the end of the first hour; 1 percent at the end of the second; 1.3 percent at the end of the third; and 1.7 percent at the end of the fourth.

Relative humidity increased from 62 percent when the observers entered the shelter to 70 percent 1½ hours later. After 3½ hours the maximum relative humidity, 73 percent, was recorded, a level maintained during the remainder of the observations. The temperature increased slightly. It was 67° F. when the occupants entered the shelter and 70° at the end of the experiment.

Phase 2 (500-gram canister)

For observation of the functional characteristics of the 500-gram KO_2 canister, as called for in the second phase of the protocol, only one investigator occupied the shelter. The atmosphere in the shelter was charged with carbon dioxide from a compressed gas tank to a predetermined concentration. Thus, although oxygen concentration of the shelter atmosphere was not appreciably changed, the carbon dioxide concentration was artificially elevated to levels consistent with prolonged occupancy. Carbon dioxide concentrations of from 1.3 percent to as high as 5 percent were used for these tests.

The flexible connection from the air intake duct was disconnected from the hand-operated blower and immersed in water, and the differential manometer flow meter was attached to the blower intake port. The blower output port was connected by a flexible tube (1-inch diameter) to the lower opening of a vertically mounted 500-gram KO_2 canister. The upper opening of the canister was connected to a standard black corrugated breathing tube. The atmosphere within the shelter of a known carbon dioxide concentration could be circulated through the canister at a known flow rate without admixture or dilution from the outside.

If the manual blower produced flow rates greater than 75 liters per minute, the corrugated tube conducted the gas that had been circulated through the canister to the breathe-through cell

Figure 3. Phase 2: Effect of altering carbon dioxide concentration in the shelter atmosphere circulated through a 500-gram potassium superoxide canister. The flow rate through the canisters remained constant at 75 liters per minute in each of the 3 experiments

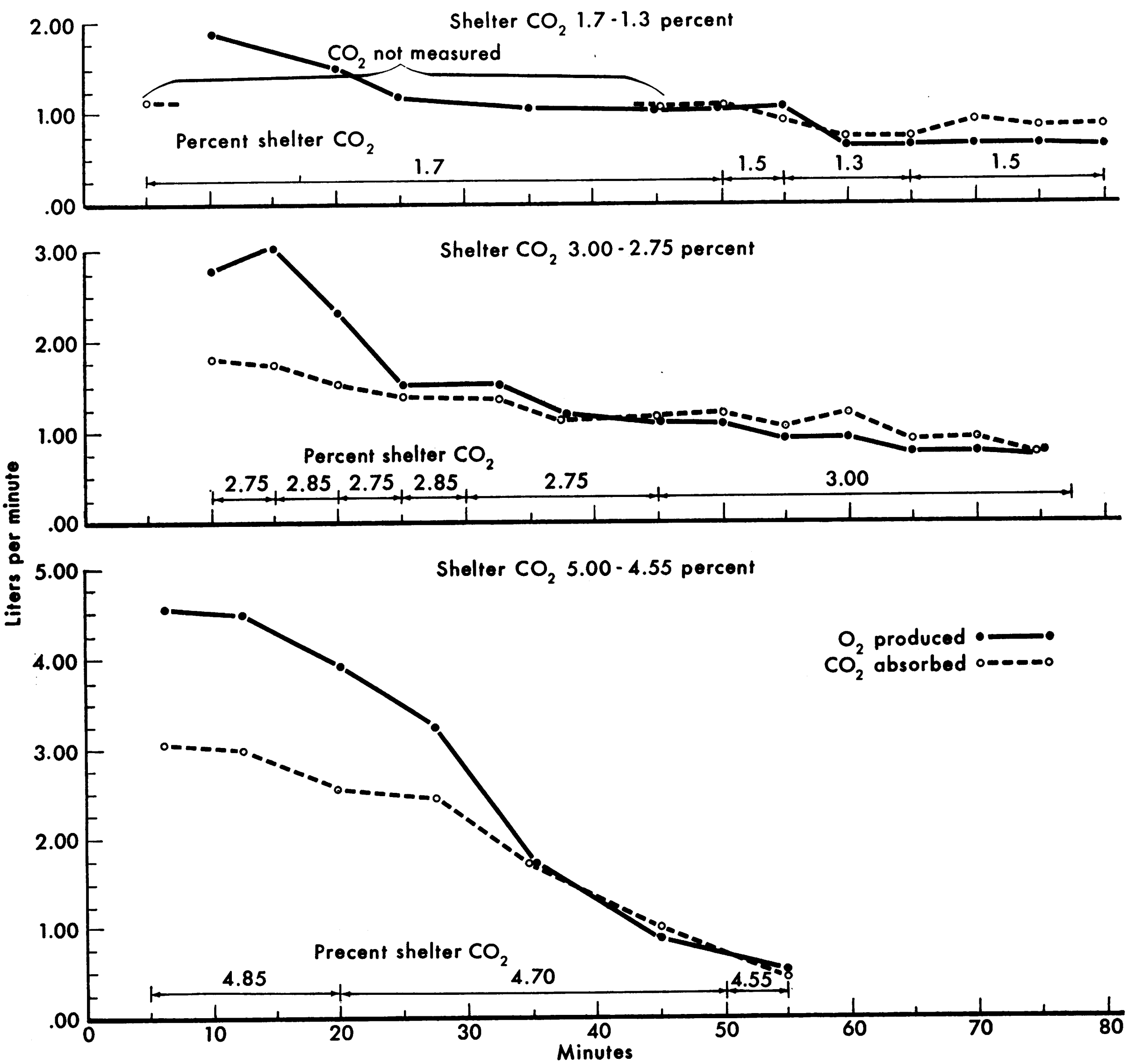
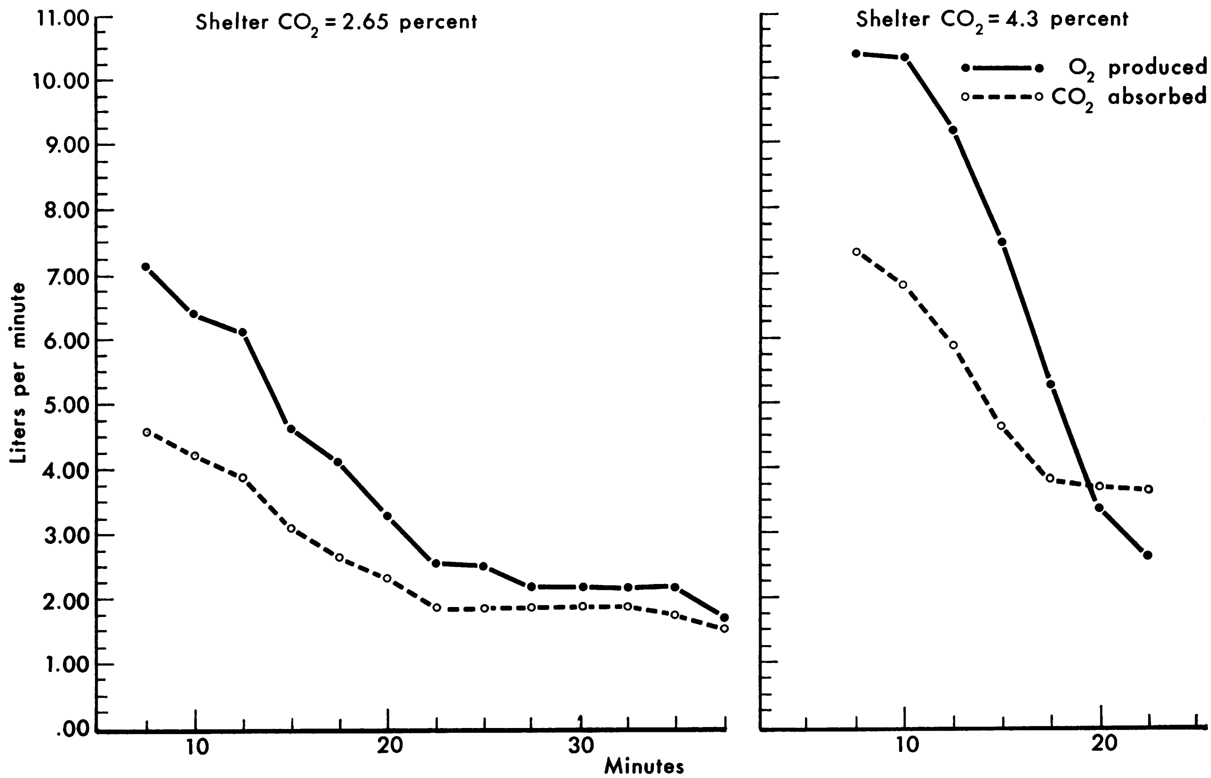


Figure 4. Phase 2: Comparison of oxygen production and carbon dioxide absorption with a constant flow rate of 175 liters per minute of shelter atmosphere containing a carbon dioxide concentration of 2.65 and 4.3 percent



of the CO_2 analyzer, and samples were withdrawn from the corrugated tube directly to the Beckman O_2 analyzer through a No. 15 needle. At flow rates less than 75 liters per minute, the total gas circulated through the canister was collected in a 120-liter Douglas bag before analysis. The volume of oxygen generated and carbon dioxide absorbed in liters per minute was calculated.

The effects of varying the circulation flow rates through the 500-gram KO_2 canister and of varying the concentration of carbon dioxide in the shelter atmosphere were determined by a number of experiments:

Flow rates, 15–200 liters per minute. A shelter atmosphere of 3.25–3.4 percent carbon dioxide was circulated through the canister at flow rates varying from 15 to 200 liters per minute (fig. 2). Each flow rate was sustained for at least 2 minutes before gas exhausted through the canister was analyzed. The period of observation was 45 minutes.

During the first 15 minutes of use of the 500-gram KO_2 canister, the volume of oxygen produced and of carbon dioxide absorbed varied directly with the flow rates. At a rate of 200 liters per minute, 5 liters of O_2 per minute were generated and 6.5 liters of CO_2 absorbed; at a rate of 55 liters per minute, 1.65 liters of O_2 were produced and 1.6 liters of CO_2 absorbed.

During the second 15-minute period, oxygen production and CO_2 absorption decreased markedly. Both functions, however, continued to vary with the flow rate through the canister, although not so markedly.

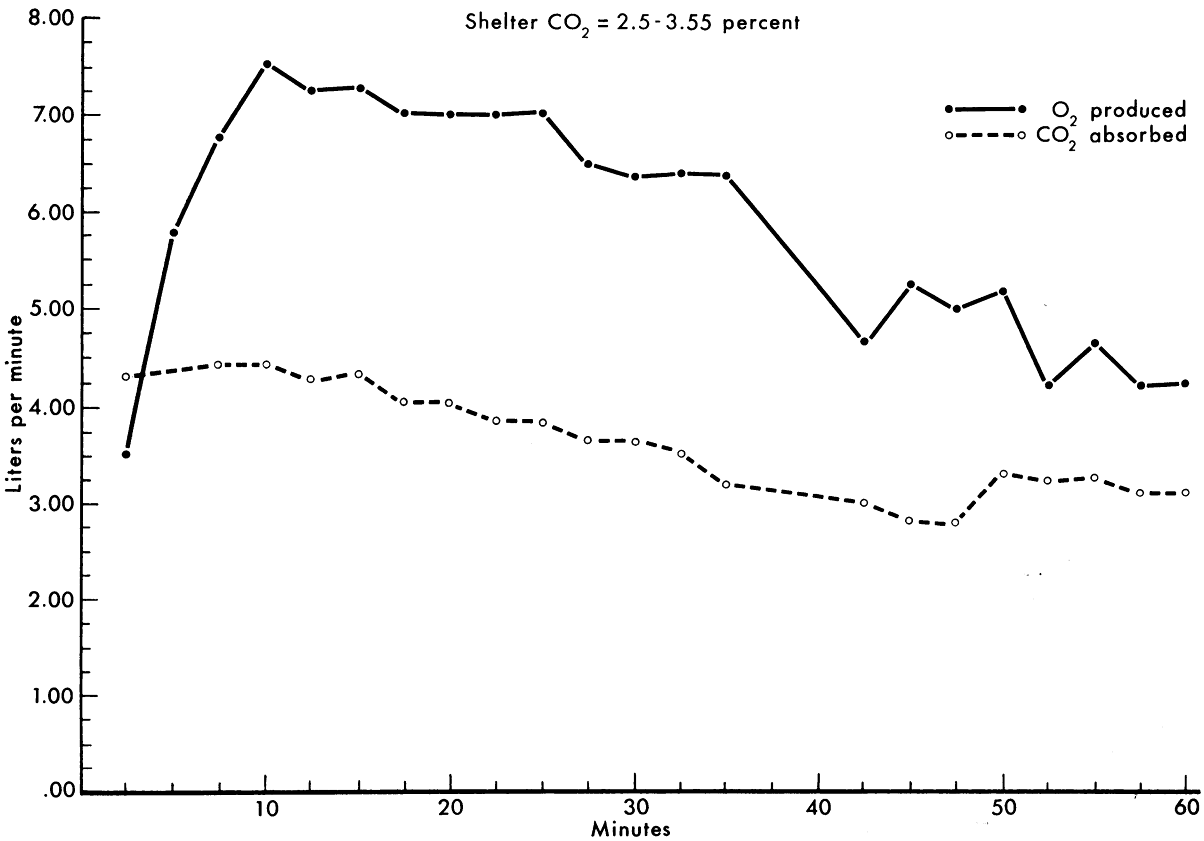
During the third 15-minute period, the volume of oxygen production and CO_2 absorption failed to vary in relation to the rate of circulation of shelter atmosphere through the canister. At a canister circulation rate of 30 liters per minute, 0.6 liters of oxygen were produced and 0.7 liters of CO_2 absorbed. Increasing the circulation rate to 120 liters per minute failed to alter these values significantly.

Varying CO_2 concentrations. Three separate experiments were conducted with the circulation flow rates of the 500-gram canister sustained at 75 liters per minute for at least 50 minutes (fig. 3). The concentrations of carbon dioxide in the shelter atmosphere were 1.3–1.7 percent, 2.75–3.0 percent, and 4.5–5.0 percent for the respective periods of observation.

In all three experiments, oxygen was generated at a rate of at least 1 liter per minute for at least 50 minutes and carbon dioxide extracted at a rate of at least 1 liter per minute for a similar time. The initial rates of oxygen generation and carbon dioxide absorption, however, were considerably increased when higher concentrations of carbon dioxide were circulated through the canister. The rates of generation and absorption fell rapidly during the remainder of the observations. The maximum oxygen generation at 75 liters circulated per minute was 4.5 liters per minute and the maximum carbon dioxide absorption was 3 liters per minute; these peaks were reached during the first 12 minutes of circulation of 4.5–5.0 percent CO_2 through the canister. Oxygen production and carbon dioxide absorption was lowest in the experiment circulating an atmosphere of 1.5 to 1.3 percent CO_2.

Flow rate of 250 liters per minute. An experiment was conducted with a sustained canister flow rate of 250 liters per minute for 30 minutes with the shelter atmosphere charged to a carbon dioxide concentration of 2.5–3.0 percent. Peak oxygen generation was 10 liters per minute during the first 10 minutes of circulation; peak carbon dioxide absorption was 6.75 liters per minute. After the first 10 minutes, the rate of oxygen generation fell rapidly, dropping to 1.25 liters per minute after 30 minutes. Carbon dioxide absorption was 4.5 liters per minute at that time. This experiment was terminated after only 30 minutes because of

Figure 5. Phase 3: Carbon dioxide absorption and oxygen production resulting from circulating a shelter atmosphere containing 2.5 to 3.5 percent carbon dioxide through a 1,250-gram canister of potassium superoxide at a flow rate of 125 liters per minute, a rate easily sustained by shelter occupants



the utter exhaustion of the investigator cranking the manually operated blower.

Flow rate of 175 liters per minute. Two experiments were conducted with a 175-liter-per-minute flow rate sustained for 25 and 30 minutes and shelter atmosphere charged to CO_2 concentrations of 2.6 and 4.3 percent (fig. 4). A relatively high rate of oxygen generation and carbon dioxide absorption was initially observed. The highest rate occurred with a shelter atmosphere of 4.3 percent carbon dioxide. In both experiments the rate of gaseous conversion rapidly declined after the first 10 minutes. A flow rate of 175 liters per minute resulted in greater carbon dioxide absorption and oxygen production than was observed, at similar concentrations of carbon dioxide, in a shelter atmosphere with a slower flow rate, 75 liters per minute, as in figure 3. Both experiments with the 175-liter-per-minute rate were discontinued at the end of 25 or 30 minutes of observation because of the physical exhaustion of the investigator operating the manually driven blower.

Phase 3 (1,250-gram canister)

A canister of the dimensions of a Roswell Park carbon dioxide absorber canister was constructed of brass and packed with 1,250 grams of KO_2 for the third phase of the protocol (fig. 5). The canister was attached in the same manner as described for the 500-gram canisters. Two observers occupied the shelter, which was charged with nitrogen and carbon dioxide until the oxygen concentration was 18 percent and the carbon dioxide concentration 3.5 percent. The shelter atmosphere was then circulated through the canister at a flow rate of 125 liters per minute for 1 hour.

The rates of oxygen generation and carbon dioxide absorption were not only initially high but also were sustained for a long period. During the first 35 minutes, oxygen generation remained more than 6.25 liters per minute and carbon dioxide absorption more than 3 liters per minute. At the end of 1 hour of circulation, oxygen generation was still more than 4 liters per minute and carbon dioxide absorption, more than 3 liters per minute. In this experiment the operators of the manually driven blower experienced no syndrome of fatigue, and the oxygen concentration of the shelter rose from an initial value of 18 percent to 18.75 percent; carbon dioxide concentration was reduced from 3.55 percent to 2.5 percent. In all our previous experiments with the 500-gram KO_2 canister, the concentration of carbon dioxide and oxygen in the shelter atmosphere had not been appreciably affected during the period of observation.

Discussion

Potassium superoxide is an extremely active chemical. Caustic in nature when fresh, it degenerates to another caustic, KOH, when discharged. It explodes violently when allowed contact with many organic materials, such as oil or grease. Obviously, such a chemical could not be distributed for untrained and uninformed persons to package in canisters themselves.

As KO_2 converts to KOH, the surface of each granule becomes coated with KOH. The KOH protects centrally located KO_2 from carbon dioxide and forms a white gummy substance which mats the granules together, causing channeling of gases and increasing the pressure difference (and consequently the work necessary to circulate gas at a given flow rate through the canister).

One might reasonably expect that the rate of oxygen generation and carbon dioxide absorption could be augmented by (*a*) increasing the volume of shelter atmosphere circulated through a canister of KO_2; (*b*) increasing the concentration of carbon dioxide in the gas circulated through the canister; and (*c*) increasing the amount of KO_2 exposed to mechanically circulated shelter air.

As indicated in the experiments, human physical endurance limits the rate at which a manual blower may be operated. It also limits the concentration of carbon dioxide which can be tolerated by persons doing physical labor.

A canister containing 1,250 grams of KO_2 provides a system which generates oxygen and absorbs carbon dioxide in large amounts for sustained periods at flow rates of canister circulation of shelter air compatible with the physical labor of operating the blower. If canisters are to be prepackaged for use in fallout shelters, it would seem that a canister of like size would be preferable to the 500-gram container used in rescue units.

The optimal internal structure for efficiency of prepackaged canisters and methods to compensate for channeling and surface alterations of granules might be considered in further investigations of canister systems.

Summary

Observations in a fallout shelter under conditions of prolonged occupancy indicate that considerably larger canisters than the 500-gram containers used in rescue units may be preferable for fallout shelters. A canister of 1,250 grams provides a system capable of generating oxygen and absorbing carbon dioxide in large amounts and for sustained periods at flow rates of canister circulation of shelter air compatible with the physical labor of operating a blower.

In experiments using the 500-gram KO_2 canister for shelter atmosphere control, concentration of carbon dioxide and of oxygen was not appreciably affected during the period of observation. In experiments with the 1,250-gram KO_2 canister, however, oxygen concentration rose from an initial 18 percent to 18.75 percent; carbon dioxide concentration was reduced from 3.55 to 2.5 percent. Moreover, the operator of the manual blower experienced no syndrome of fatigue; in two experiments with the 500-gram canister such syndromes had occurred.

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EQUIPMENT REFERENCES

(A) MSAR Chemacon canister. Chemacon Atmospheric Control. Mine Safety Appliances Research Corp., Callery, Pa.

(B) MSAR Chemox oxygen generating canister. Mine Safety Appliances Corp., Pittsburgh, Pa.

(C) Manually operated blower No. 60. Champion Blower & Forge Co., Lancaster, Pa.

Increasing Number of Psychiatrists

A growing number of physicians in the United States have been specializing in psychiatry, according to a recent tabulation of the American Psychiatric Association and the National Institute of Mental Health, Public Health Service. The 16,863 psychiatrists currently in active practice represent a new high in this medical specialty. They comprise 6.3 percent of the 267,950 licensed physicians in the country. Moreover, it is estimated that of all medical students enrolled today, 9.4 percent enter psychiatric residency training.

Approximately 2,000 training stipends in the specialty were awarded in 1964 through Federal financial support, and States have increased their support of residency programs. The expanding national mental health program also offers increased professional opportunities.

The tabulation included data based not only on membership in the American Psychiatric Association but also information on other psychiatrists obtained from the American Medical Association and from an NIMH survey of mental health establishments. The findings were reported in Mental Health Manpower Current Statistical and Activities report, October 1964, prepared by the National Institute of Mental Health.